Migration to 3G Technology Standards: Europe, Japan, South Korea, and the U.S.

By Richard Nunno, International Bureau, FCC
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For over a decade, the International Telecommunication Union (ITU) has been supporting the international effort to develop an advanced third-generation (3G) mobile telecommunications service that has a higher bandwidth than previous and existing mobile services and that subscribers can seamlessly use across international borders (known as global roaming). To that end, the ITU has identified spectrum and developed technical standards for International Mobile Telecommunications 2000 (IMT-2000), the official name for 3G services. The ITU's World Administrative Radiocommunication Conference (WARC) in 1992 and World Radiocommunication Conference (WRC) in 2000 identified several bands of spectrum that could be used for 3G services.

The mobile telecommunications industry has started delivering 3G services that provide broadband applications including voice, data, and video. 3G signal transmission rates are reaching 2 megabits per second (Mbps) or higher for indoor (low mobility) wireless applications (more than 35 times faster than today's 56 kilobits per second (kbps) dial-up PC modems). 3G rates may be slower (384 kbps) for pedestrian traffic, and 144 kbps for high mobility (vehicular) traffic.[1]

How each country is implementing 3G systems depends on a number of factors, such as the country's 3G spectrum allocations, the standards it adopts for 3G (if it adopts any standards vs. letting the marketplace make the decision), and the country's current mobile telephony system configuration. Because a great deal of information and analysis is already available on the spectrum-related issues surrounding 3G implementation, this report focuses only on the technology standards issues pertaining to 3G. This report reviews the standards used in existing mobile telephony systems in the United States, the European Union (EU), Japan, and Korea, and compares how these countries/regions are making the transition to 3G services. For a discussion of the spectrum-related issues surrounding 3G services, see the Commission's 3G proceedings, Docket Nos. ET 00-258 and WT 02-353.

Background—Existing 2G Standards

Second generation (2G) mobile telephony systems, also known as personal communications services (PCS), were developed and deployed in the early to mid-1990s, in response to the rapid growth in first-generation cellular subscribership.[2] 2G systems

[1] FCC website at http://www.fcc.gov/3G/#sec2.

[2] The main first generation cellular systems are Advanced Mobile Phone System (AMPS, also known as IS-54), Nordic Mobile Telephone (NMT), and Total Access Communication System (TACS), operating

were distinguished from the first-generation cellular systems by the use of digital signal transmission techniques and some operated on a higher frequency band (primarily 1850-1990 MHz). This enabled the efficient transmission of data as well as voice information content, plus a longer battery life and a host of other digitally-based services such as call waiting, call forwarding, caller ID, and encryption.

Multiplexing several telephone calls in one channel for 2G systems is typically accomplished by dividing the transmitted signal into segments according to either time, frequency, or a code. The technical standards used to accomplish this are known as "air interface standards." While frequency division techniques are used in some signal transmission systems, they are not used for cellular and PCS systems and thus will not be discussed here. The main standards used for digital mobile telephony services are: Time Division Multiple Access (TDMA), Global System Mobile Communications (GSM), integrated Digital Enhanced Network (iDEN), and Code Division Multiple Access (CDMA). Another standard called cellular digital packet data (CDPD) is used to provide an overlay network on existing cellular spectrum to allow data rates up to 19.2 kpbs.

TDMA and GSM. The TDMA standard (originally known as Interim Standard-54, or IS-54, but now known as ANSI-136), developed in the United States, provides each call with a time slot (on the order of a millisecond) so that several calls can be contained within one channel. The implementation of TDMA, which allots six time slots to each channel, has provided up to a six-fold increase in information carrying capacity in the same bandwidth as a single AMPS channel. With the utilization of hierarchical cells, intelligent antennas, and adaptive channel allocation, the capacity can approach 40 times AMPS capacity.[3] The Global System for Mobile Communications (GSM) standard, developed by the European Telecommunications Standards Institute (ETSI), is a variation of TDMA, in which the signals of eight calls are multiplexed in time over a single channel. The iDEN standard is another variation of TDMA technology.

CDMA. Code division techniques, which for mobile telephony systems are embodied by the CDMA standard (known in the United States as ANSI-95), utilize a process that had been used extensively for military purposes known as the "spread spectrum" technique. The transmitted energy of a spread spectrum signal is spread over a range (or band) of frequencies, so that the energy level at any one frequency is very low. This technique reduces the possibility of causing harmful interference to other wireless devices operating in the same frequency range, and also makes the devices more resilient against jamming. Spread spectrum systems can also dynamically adjust capacity and coverage in response to variations in the call load. CDMA 2G systems in the United States (the commercial name is cdmaOne, a trademark of the CDMA Development Group) employ a unique code to distinguish each call, which allows many users to occupy the same time and frequency (channel) in a given band. CDMA proponents claim

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on bands around 800 MHz. Although these systems originally used analog signal transmission, most of them have been upgraded to digital signal transmission, so that they are now equivalent to 2G systems.

[3] Time Division Multiple Access, Web ProForum Tutorials, International Engineering Consortium, http://www.iec.org.

that CDMA systems provide increased capacity and improved performance and reliability over frequency division and time division systems, while GSM proponents refute that assertion.

Status of Mobile Network Deployment in Selected Regions

United States. In its rules for implementing digital cellular and PCS, the United States did not select a standard, instead allowing the licensees to choose whatever standard they felt would best meet their customers' needs (a policy called *technology neutrality*). While all of the above standards are still used in the United States, ANSI-136 TDMA is being phased out as its main advocates, AT&T Wireless and Cingular Wireless, have begun overlaying their existing TDMA networks with GSM (along with a more advanced technology called GPRS).[4] Other ANSI-136 networks are evolving to cdma2000 networks. Furthermore, the trade group that had represented TDMA technology has dissolved.[5]

AT&T Wireless still expects to use TDMA for many years, but is overlaying GSM/GPRS on its TDMA network in order to improve its wireless data capabilities and enhance its migration to 3G technology.[6] By the end of 2001, AT&T Wireless had rolled out GSM/GPRS to 45 percent of the POPs covered by its network.[7] AT&T Wireless has also begun to deploy GSM/GPRS in the network that it recently acquired through the purchase of TeleCorp.[8] Cingular Wireless, which currently has a mix of TDMA (covering 70 percent of its POPs) and GSM (covering 30 percent of its POPs) networks, announced in October 2001 that it would overbuild its entire TDMA and remaining analog networks with GSM/GPRS.[9] Cingular Wireless expects to have 50 percent of its POPs covered with GSM by the end of 2002 and the remainder covered by the end of

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[4] In January 2002, Cingular began field testing a new technology, known as GAIT (GSM/ANSI-136 Interoperability Team), that allows users to move with one handset between TDMA and GSM technologies on both broadband PCS and cellular spectrum bands. *Network Enhancements to Enable Cingular Customers to Access Both GSM and TDMA*, News Release, Cingular, Jan. 16, 2002.

[5] *Universal Wireless Communications Consortium Completes Organizational Objectives*, News Release, Universal Wireless Communications Consortium, Dec. 26, 2001. In March 2002, a number of wireless carriers and equipment manufactures, including AT&T Wireless and Cingular, formed a new trade association, called 3G Americas, to promote the GSM and TDMA family of technologies. *3G Americas to Represent Global Technologies in the Americas*, News Release, 3G Americas, Mar. 13, 2002.

[6] AT&T Wireless has indicated that it does not plan to aggressively migrate users to its GSM network. Paul Wuh *et al*., *Goldman Sachs AT&T Wireless Group*, Global Equity Research, Feb. 8, 2002.

[7] Goldman Sachs AT&T Wireless Group.

[8] AT&T Wireless began to deploy GSM/GPRS infrastructure in TeleCorp's coverage area beginning in the second half of 2002.

[9] *Cingular Moves to the Edge*, News Release, Cingular, Oct. 30, 2001; *Cingular Announces Technology Path*, speech by Stephen Carter at the Righa Royal Hotel, New York, NY, Oct. 30, 2001 (*available in* http://www.cingularwireless.com/about/speech_01_10_30).

2003.[10] Cingular Wireless will continue to provide TDMA service to its current customers, but it expects that many will upgrade to GSM technology over time.[11] Cingular Wireless' national network upgrade will cost approximately $3 billion.[12] Cingular Wireless and AT&T Wireless are building a GSM/GPRS network along 3,000 miles of interstate highways in a number of western and midwestern states.[13] As a result of these industry developments, GSM is often no longer distinguished from TDMA. Instead, the two are considered as one migration path towards more advanced digital capabilities, recognizing that TDMA as currently deployed will continue to be used by millions of subscribers for a number of years.

Of the other four nationwide mobile telephone operators, Sprint PCS and Verizon Wireless use CDMA, VoiceStream/T-Mobile uses GSM, and Nextel uses iDEN.

European Union. The average mobile phone subscribership penetration among the 15 EU countries as of 2001 was 76%, compared to 44% in the United States. Unlike the United States, which allowed each of its digital cellular/PCS licensees to choose its own signal transmission standard, the EU adopted GSM as the standard for its member countries (GSM is also used in some non-EU European countries, as well as Australia, and much of Asia and Africa). Mobile telephone users in those regions can buy one phone (called a "world phone") that operates across multiple bands and, thus can work anywhere the GSM standard is supported, provided commercial contracts among operators are in place. To connect to the network in another European country, GSM users simply switch subscriber identification module (SIM) cards. SIM cards are small removable integrated circuits that slip in and out of GSM cell phones, and store the connection data and identification numbers needed to access a particular mobile service provider.[14] Many claim that the EU's adoption of GSM as a single standard was one reason for the higher cellular penetration in EU countries compared to the United States.

Japan. Japan uses a standard called Personal Digital Cellular (PDC), another variation of TDMA technology (with a different modulation scheme from either GSM or ANSI-136 TDMA), for its second-generation mobile networks. NTT DoCoMo Inc. (the largest mobile services provider in Japan) and J-phone (the third largest mobile provider) use PDC, while KDDI (the second largest mobile services provider) has switched its network from PDC to CDMA (cdmaOne).

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[10] Ric Prentiss, *Cingular Announced GSM Overbuild Plans*, Email Alert, Raymond James, Oct. 30, 2001.

[11] *Cingular Moves to the Edge*, News Release, Cingular, Oct. 30, 2001

[12] Ric Prentiss, *Cingular Clues Us In on '02 CapEx Plans*, Equity Research, Raymond James, Nov. 6, 2001

[13] Dobson To Upgrade Network to Wireless Standard, REUTERS, Jan. 29, 2002.

[14] See www.howstuffworks.com/cell-phone.htm, section on cellular access technologies.

A standard called i-mode, introduced by DoCoMo, is used as an enhancement to PDC technology for providing Internet connection services via cell phones (or "mobile Internet"). Japan is the largest market in the world for mobile Internet, with 52 million subscribers as of March 2002.[15] I-mode, a type of packet-switched technology, uses compact HTML to provide over-the-air-data transmissions. KDDI uses a different standard for Internet access called EZ-Web, and J-Phone's standard for Internet access is called J-Sky. Data services are not interoperable among these three carriers, not even between DoCoMo and J-phone.

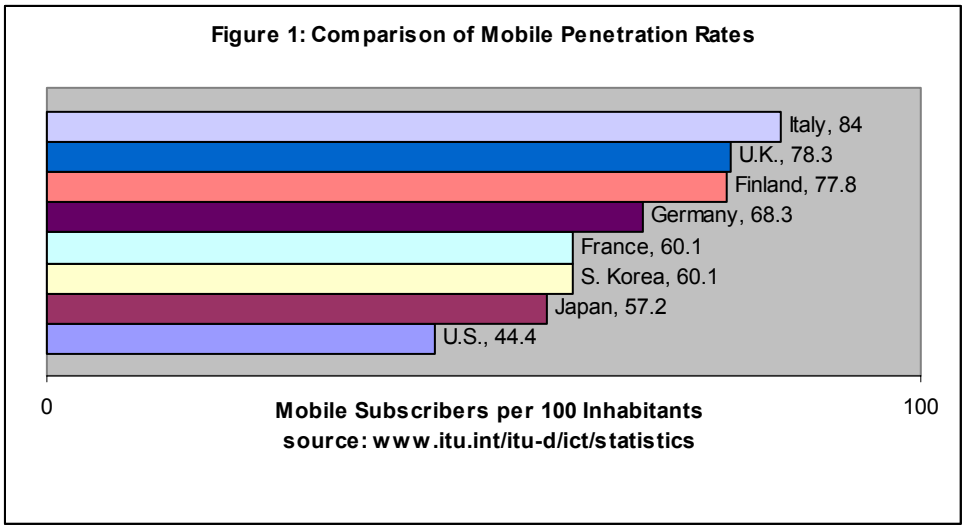
South Korea. In 2001, S. Korea surpassed Japan in its mobile phone penetration (62% compared to Japan's 58%), but still remains lower than several EU nations. S. Korea has three mobile operators: SK Telecom (the largest), Korea Telecom Freetel (KTF, the second largest), and LG Telecom Ltd. (Korea's smallest mobile carrier).

Table 1 shows which mobile telephony signal transmission standards are used by some of the main mobile services providers in selected countries. Figure 1 shows the mobile phone penetration rates for selected countries.

Table 1: Mobile Telephony Standards Used in Selected Countries

	TDMA	GSM	CDMA	iDEN	PDC
United States	AT&T, Cingular	AT&T, Cingular, T-Mobile (Deutsche Telecom)	Sprint PCS, Verizon	Nex-tel	
Japan			KDDI		DoCoMo, J-phone
Germany		T-Mobile, D2 (Vodafone), E-Plus (KPN, NTT, Hutchison), Quam, O2, MobilCom			
France		Orange (France Telecom), SFR (Vivendi), Souyges Telecom			
United Kingdom		BT Cellnet, Orange, One2One (Deutsche Telecom), Vodafone			
Italy		TIM (Telecom Italia Mobile), Vodafone/Omnitel, Wind Infostrada			
S. Korea			LG Telecom		SK-Telecom, KTF
Netherlands		KPN Mobile, Libertel (Vodafone), BEN (Deutsche Telecom), Dutchtone, Debitel, mm02			

[15] *Stirring of the IT-Prevalent Society*, White Paper 2002, Ministry of Public Management, Home Affairs, Posts and Telecommunications, Japan. Page 9.



Technology Upgrades

Existing mobile networks have introduced several upgrades that make 2G services appear to users like 3G features. These are often referred to as 2.5G systems. Some of the main innovations are described below:

CODEC. Enhanced speech compression/decompression (**CODEC**) is a specialized computer program that reduces the number of bytes used by large files (such as a video file) and programs by eliminating redundancies in data in order to minimize the amount of storage space needed. CODECs are often used to speed up wireline Internet transmissions of large files, but are particularly important in wireless transmissions, which usually have significantly lower bandwidth than wireline. CODECs can be used with any existing mobile telephony standard.

CAMEL. Another enhancement to GSM networks, customized application for mobile enhanced logic (CAMEL), enables "intelligent network" services such as pre-paid calling, call screening, supervision, and location identification. These services are often packaged together in what is called a "virtual home environment" to enable the services previously offered only at home to other locations.

Packet Switching. Information signals (voice or data) was traditionally transmitted over telephone networks in what is called circuit-switching, in which a communications path is established between two parties and is dedicated exclusively to one conversation for he duration of the call. Another technique called packet-switching (originally used for computer data transmissions) digitizes the information and breaks it down into smaller pieces called packets. Each packet contains a small part of the message content along with call-identifying information called a "header" that indicates the origination and destination points of the information. Each packet is transmitted separately and is reassembled into the complete message at the destination point.

Packet switching is considered a more efficient use of a network than circuit switching because the same bandwidth can be used for multiple communications simultaneously (called multiplexing). The packet-switched mode is used in all Internet communications, and is increasingly being used in telephone networks (both wireline and wireless). Packet switching is being implemented on many of today's wireless networks, and will be the standard for all 3G systems. One popular application of packet switching is Short Messaging Service (SMS), which enables handsets to send messages up to 160 alphanumeric characters to each other. Typical uses of SMS include notifying a mobile phone owner of a voicemail message, notifying a salesperson of an inquiry and contact, and notifying a doctor of a patient with an emergency problem.

WAP. Wireless Application Protocol is a packet-switched standard used to provide Internet browsing using a portable terminal. The WAP standard can be used with any mobile telephony standard, and is used by mobile service providers in many countries, for applications such as SMS, multimedia messaging service (MMS) and snap-on digital cameras. DoCoMo's i-mode can work with WAP to provide data transmissions. However, WAP has failed to achieve wide acceptance due to complaints of poor performance on mobile phones, and is being phased out by many mobile service providers as they upgrade to other technologies.

HSCSD. High-speed circuit switched data, the first enhancement to GSM service, enables GSM users to transmit data three times faster than the standard data rates of GSM networks. HSCSD allows users to access their company LANs, send and receive e-mails, and access the world wide web using either a mobile phone or a PCMCIA card installed in a notebook computer or other portable device.

GPRS. General Packet Radio Service is a software upgrade to existing TDMA and GSM networks to provide wireless access to external IP-based (packet-switched) networks, such as the Internet and corporate intranets. GPRS (sometimes referred to as 2.5G) introduces packet switching to the core network, allowing direct access to packet data networks. The upgrade enables high data rate (up to 115 kbps) packet switched transmission through the GSM network so that end users can remain connected to the external network indefinitely. GPRS provides medium-speed, packet-based, wireless data applications.[16]

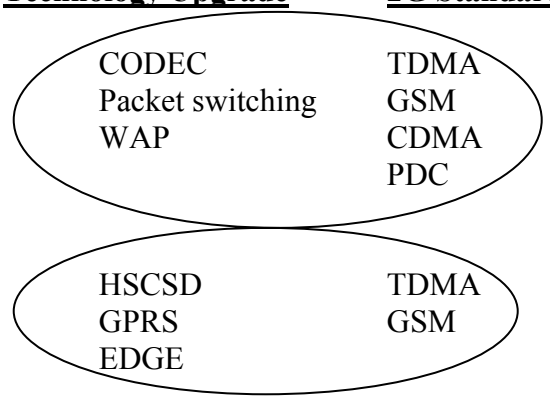
EDGE. The next step in the evolution of GSM toward high-speed data applications is Enhanced Data Rates for GSM Evolution (EDGE). EDGE, a packet-switched protocol, enables a data rate of 384 kbps by using all eight time slots and a modulation technique called 8-phase shift keying (8PSK). This data rate is sufficient to qualify an EDGE-enhanced network as a 3G service (without the need to use new spectrum). Higher speeds may be available in good radio conditions low ambient noise, good weather, etc.). EDGE is used for the delivery of multimedia and other broadband services to mobile phone users. To implement EDGE services, software upgrades are required to the

[16] *Generations: 1G-4G*, a publication of LCC International, Inc., 2001.

network, new transceivers must be added to each cell, and consumers must purchase EDGE-capable handsets.[17]

Figure 2 below shows that many of these technology upgrades can be applied to all of the main 2G signal transmission standards, whereas others are only applicable with the TDMA/GSM standards, and are not compatible with CDMA technology.

Figure 2: Applications for Technology Upgrades



Migration Paths to 3G

Standards Developments. In May 2000, the ITU approved a set of five radio interface standards for 3G systems from proposals submitted by regional standards developing organizations (SDOs). The SDOs include the European Telecommunications Standards Institute (ETSI), the Telecommunications Industry Association (TIA, representing North America), the Association of Radio Industries and Business (ARIB, representing Japan), the China Wireless Telecommunications Standards Group (CWTS), the Telecommunications Technology Association (TTA, representing Korea), and the Telecommunication Technology Committee (representing Japan). The 3G standards, along with their alternative names, are shown and described below:

IMT-DS CDMA Direct Spread also called UMTS, WCDMA	IMT-MC CDMA Multi-Carrier also called cdma2000	IMT-TC CDMA Time-Code also called CDMA TDD, TD-SCDMA, UTRA TDD
IMT-SC TDMA Single Carrier also called UWC-136, EDGE	IMT-FT FDMA/TDMA Frequency-Time also called DECT	

- **WCDMA.** The common name for the first of the above standards (CDMA Direct Spread) is Wideband CDMA, or WCDMA, which uses a 5 MHz bandwidth for

[17] http://www.nonvoice.com/edge.htm.

each channel. This standard was established in 1998, when the EU Commission adopted a "Common Position" to promote the implementation of 3G, called the Universal Mobile Telecommunications Service (UMTS, another common name for this standard) with WCDMA as the standard. Since Europe currently uses GSM as its 2G standard, WCDMA is seen as the logical migratory path for GSM systems where the necessary spectrum is available.

- **cdma2000.** This standard (also called CDMA Multi-Carrier) is successor to CdmaOne and includes three modes of operation, including cdma2000 1x, 1xEV-DO, and 1xEV-DV. The 1x mode uses a channel bandwidth of 1.25 MHz and can double the voice capacity of CdmaOne networks and delivers peak packet data speeds of 307 kbps in mobile environments. The 1xEV-DO mode increases the data rate of cdma2000 1x to a peak rate of 2.4 Mbps, allowing access to more bandwidth-intensive applications. The 1xEV-DV mode provides integrated voice and simultaneous high-speed packet data services, such as video, video-conferencing and other multimedia services at speeds of up to 3.09 Mbps.[18] All three modes are backward compatible with each other and with cdmaOne.

- **CDMA TDD.** This standard (TDD is for time division duplex) combines both CDMA and TDMA techniques to separate the transmitted and received transmission because it uses the same carrier channel for both. Other technologies use a separate channel for each direction, so this technology uses half the bandwidth of other systems. CDMA TDD is also referred to as UTRAN TDD (Universal Terrestrial Radio Access Network) and is also called TD-SCDMA (the "S" stands for synchronous). It operates at two "chip rates," 1.28 Mbps in which it uses a channel bandwidth of 1.6 MHz, and 3.84 Mbps in which it uses a channel bandwidth of 5 MHz. This system was developed by China's government, which reportedly believes it is a smooth and economical way to migrate from GSM to IMT-2000. However, the migration process is less clear for this system than it is for either WCDMA or cdma2000.

- **TDMA Single Carrier.** These radio interface specifications were developed by TIA with input from the Universal Wireless Communication Consortium (in developing a standard called UWC-136) to allow TDMA or GSM systems to migrate to IMT-2000. It uses a 1.6 MHz channel and incorporates EDGE technology to provide IMT-2000 services. Since it uses less bandwidth than WCDMA, it is an alternative for TDMA or GSM 2G systems where additional bandwidth is not available. There are no current plans to utilize this standard in any country.

- **FDMA/TDMA.** This standard, also known as digital enhanced cordless telecommunications (DECT), was defined by ETSI. It is a TDMA TDD system

[18] For further information on cdma2000 characteristics, see the CDMA Development Group website at http://www.cdg.org/technology/3g.asp.

that operates with a channel bandwidth of approximately 1.728 MHz. There are no current plans to utilize this standard in any country.

A fundamental requirement by the ITU is that the resultant systems must be interoperable. However, despite promises from the manufacturers and mobile service providers, it is not clear to what extent the different 3G standards adopted in various countries will be interoperable. Equipment manufactures assure the regulators that chips can be designed for the handsets to support whatever technologies they want, and thus could work across different networks.[19]

Industry Efforts. WCDMA, CDMA TDD, and TDMA-SC are being developed by the Third-Generation Partnership Project (**3GPP**), a joint venture of the five SDOs listed above (under Standards Developments).[20] 3GPP has been releasing WCDMA in phases and annual releases. The first release, issued in December 1999, defined enhancements and transitions for existing GSM networks. The second release, issued in December 2000, provided similar enhancements for TDMA and CDMA networks. The main feature of the first release is the adoption of the UMTS terrestrial radio access (**UTRA**) interface. UTRA supports time division duplex (TDD)[21] for public micro- and pico-cells (much smaller cells than the typical cellular networks) and unlicensed cordless applications. It also supports frequency division duplex (FDD) for wide area macro- and micro-cells.

The migration of GSM networks to WCDMA could take a path from the 14.4 kbps GSM rates to 57.6 kbps (using HSCSD), then to 115 kbps (using GPRS), then to 384 kbps (using EDGE), and finally to 2 Mbps (using UMTS). TDMA systems could be upgraded to greater capacities (using 30 kHz channels) in phases from 28.8 kbps, to 64 kbps (IS-136+), then to 384 kbps (EDGE – adding a 200 kHz channel), and finally to rates up to 2 Mbps by adding a 1.6 MHz channel.[22]

Because the 3GPP consortium focused on the migration paths for GSM/TDMA technologies to 3G, companies using CDMA technology for their existing 2G services decided to form a separate group, called **3GPP2,** to address specifically the migration of CDMA-based mobile services to 3G. The members of 3GPP2 are the same SDOs as are in 3GPP, except that Committee T1 and ETSI are members of 3GPP and TIA a member of 3GPP2.[23] CDMA (ANSI-95) systems will be upgraded to 115 kbps (ANSI-95B), then

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[19] Statement in an e-mail by Dan Bart, Telecommunications Industry Association, March 20, 2003.

[20] See http://www.3GPP.org. Also, for background see *UMTS Protocols and Protocol Testing*, Tektronix, Web Proforum Tutorials, International Engineering Consortium, **http://www.iec.org**.

[21] Duplex refers to a two-way simultaneous signal transmission capability.

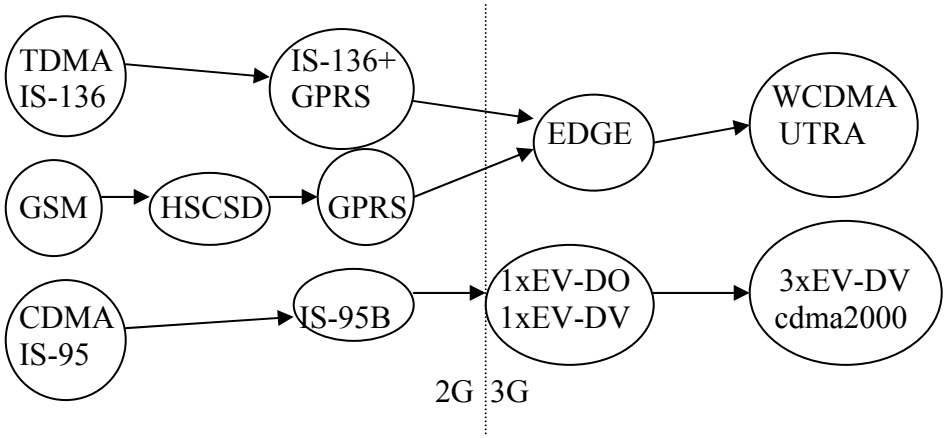
[22] ITU Handbook on Deployment of IMT-2000 Systems, draft version 0k_sec: 2 December 2002

[23] See **http://www.3GPP2.org** for further information. In addition, several other new industry interest groups have emerged—3GIP and MWIF were initiated to drive development of IP-based 3G networks. The Open Mobile Alliance (OMA) is working on consolidating many of these fora.

to 307 kbps (1xEV-DO, a data overlay network), or to 1xEV-DV (incorporating both data and voice on the same channel), and finally to 2 Mbps with 3xEV-DO (also called IS-2000, Wideband cdmaOne or cdma2000). For most ANSI-95 operators, the migration path to 3G will be seamless and reverse-compatible: the 2G handset will operate on 3G networks, and the 3G handsets will be able to operate on 2G networks. This transparency for users, along with the ability to roam seamlessly across 2G and 3G platforms, gives operators flexibility in deployment timing. Segments of the network can be upgraded where capacity enhancements or higher data speeds are essential, while other segments can remain interoperable.

Figure 3 below depicts the likely migration paths to 3G for TDMA, GSM, and CDMA systems. The ITU is developing a handbook on the deployment of IMT-2000 (3G) systems globally, designed to help countries plan for the migration to 3G systems in a harmonized way. This document, when completed, should clarify some of the questions regarding the potential migration paths to 3G.

Figure 3: Migration Paths to 3G



3G Implementation by Regions. As discussed above, the EU has adopted WCDMA as its 3G standard. To ensure a pan-European service, one 3G licensee in each national market is required to use WCDMA, but the EU will not prohibit other standards for other licenses issued. Some European carriers are using the cdma2000 standard is in use. However, it seems unlikely that smaller carriers would choose a different standard and face potential interoperability problems with the dominant 3G carrier.

The U.S., following the same reasoning as with 2G implementation, has maintained technology neutrality, and has not adopted any one 3G standard, but will instead allow mobile service providers to choose the standard they believe is best suited to their needs. Of the six national carriers, a likely scenario would be for the carriers currently using CDMA (Verizon and Sprint PCS) to migrate to cdma2000, and for the carriers using TDMA/GSM/iDEN (AT&T, Cingular, T-Mobile, NexTel) to migrate to WCDMA.

In Japan, MPHPT has adopted both WCDMA and cdma2000 for 3G implementation. DoCoMo and J-phone use WCDMA, and KDDI uses CDMA2000. No other standards have been proposed by a Japanese mobile services provider. Japan's three mobile service providers have already provided Internet access over their 2G networks, and are in various phases of migrating these services to 3G. In October 2001, NTT DoCoMo began offering IMT-2000 (3G) services to Japanese consumers using the WCDMA standard. By February 2003, DoCoMo reported over 154,000 3G subscribers.[24] An enhanced version of DoCoMo's i-mode service (called FOMA for Freedom of Multimedia Access) is considered a 3G service. KDDI began offering 3G services in April 2002 using the cdma2000 standard (originally called EZ-Web service). By February 2003 KDDI had over 5.3 million 3G subscribers. J-Phone began 3G services in December 2002, and had recorded 4,700 3G subscribers by February 2003.

The S. Korea government granted 3G licenses in 2000 to provide commercial 3G services to two consortia led by SK Telecom and KTF, and gave a third license to LG Telecom. SK Telecom was the first company in the world to offer commercial 3G services in October 2000, followed by KTF and LG in May 2001.[25] By January 2003, Korea had recorded over 17 million 3G subscribers. SK Telecom and KTF originally intended to deploy 3G systems using WCDMA technology,[26] but instead they both deployed cdma2000 technology. LG had always planned to use cdma2000. The Korean system was supposed to deliver data at speeds up to 2.4 Mbps to Internet-equipped phones, but this rate has not been reached due to technical problems.[27]

Worldwide. As of February 2003, there were 37 commercial 3G operators in 19 countries with over 32 million 3G subscribers. Because many of those operators do not publicly report their subscriber numbers, the real total number of 3G subscribers could be much higher.

The capabilities of some of the IMT-2000 terrestrial radio interfaces are already being enhanced and extended up to 10 Mbps and could reach 30 Mbps (under optimal signal and traffic conditions) by 2005. These high data rates could generate a demand to upgrade the access network with a new technology.[28]

Even if the different 3G standards are worked out to be interoperable with each other, there could still be problems achieving interoperability between the 3G and some of the previously existing 2G systems. Some industry analysts claim that this might be more of a problem for the TDMA/GSM-based 2G systems than it will be for the CDMA-based systems.

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[24] *3G Is Here Today*, February 10, 2003. http://www.3gtoday.com/operators_noflash.htm.

[25] *3G is Here Today,* February 20, 2003.

[26] *3G in Korea*, Merrill Lynch Global Securities and Economics Group, 6 September 2002.

[27] *KTF Blazes Trail into 3G Future*, Korea Times, October 29, 2002.

[28] Memo provided by Charlie Breig on *International Developments on IMT-2000* (no date or author).

Technology-Related Issues in the Implementation of 3G

Competing Standards. Some U.S. policy-makers have expressed concern over the EU's adoption of a single 3G standard, and whether that action might confer a market advantage for WCDMA over other competing services. EU officials have stated that to ensure a pan-European service, one 3G license in each national market is required to use WCDMA technology, but the EU will not prohibit other technologies for other licenses issued. Some individual EU member states, however, have adopted policies that discriminate against other technologies competing in their markets. Even if individual member states' are technology neutral, market incentives in Europe could cause WCDMA to predominate.

Competition from Wi-Fi. Many observers are concerned that some of the demand for the data portion of 3G services will be taken away by a new unlicensed wireless service called Wi-Fi (for wireless fidelity, also called 802.11, the IEEE standard established for the data transmission technology).[29] Wi-Fi systems were originally intended to enable wireless LANs, but have also come to be used for mobile phone connections to LANs (some also using Bluetooth technology), enabling mobile phone users to gain access to data services available on LANs. Some 3G proponents fear that consumers could simply use Wi-Fi systems in conjunction with their existing mobile phone services to circumvent the need for greater bandwidth, and more expensive, 3G services.

Even from the consumers' perspective, however, Wi-Fi systems are not exactly comparable to 3G systems for several reasons. First, Wi-Fi is designed for use within smaller areas (such as a building) than 3G, which is intended to operate over larger geographic areas. Second, Wi-Fi has a much greater bandwidth (up to 11 Mbps using the 802.11b standard, and up to 54 Mbps using the 802.11a standard) than 3G, which can operate only up to 2 Mbps for stationary applications, and less for mobile applications. Third, consumers can use Wi-Fi systems without having to subscribe to any service. They can simply purchase Wi-Fi equipment and install it on a LAN or at home. While voice applications over LANs and the Internet are available, they are not yet as easy to use as cellular systems, and they are not intended for mobile applications over large distances as are cellular systems. In the long run, Wi-Fi systems may become more complimentary than competitive to 3G systems, fulfilling the in-building demand for mobility, while 3G systems handle the out-of-building demands. It is not clear which 3G standard would facilitate handing-off between Wi-Fi and 3G systems, or whether such interoperability could be optimized if 3G standards are developed accordingly.

Intellectual Property Rights for 3G Technologies. The Interoperability of 3G services is dependent on the cooperation of the equipment manufacturers as well as the service providers. While the 3GPP is using WAP as the transport protocol for advanced services provided over GSM-based networks, the 3GPP2 (the CDMA consortium) has

[29] *Wi-Fi Hot-Spot Networks Sprout Like Mushrooms*, IEEE Spectrum, September 2002. pages 18-20.

not adopted any single protocol for that function. Qualcomm Inc. profits from patent royalties when service providers and manufacturers use its CDMA-based patents, while competing companies, such as Nokia, NTT DoCoMo Inc., LM Ericsson, and Siemens might have an advantage if the service provider uses another standard (which might have fewer Qualcomm patents), because they would pay fewer royalties to Qualcomm.[30] Qualcomm is currently marketing a software program called BREW (Binary Runtime Environment for Wireless) that enables users to download applications onto their mobile phones. Competing manufacturers claim that BREW favors CDMA-based applications, which places them at a disadvantage.[31] Many of these companies are lobbying the telecom regulatory authorities in various countries to establish policies that exclude their competitors. Nevertheless, the U.S. policy of technology neutrality for telecom services providers also applies in this case.

Delays in 3G Deployment. With the downturn in the global economy in general, and in the telecom industry in particular, several telecom services providers have decided to delay 3G service launches. For example, of the 18 new European 3G competitors, 11 have abandoned plans to build.[32] Most of the operators are blaming the delays on technological issues rather than on lack of anticipated demand. Some operators indicate "soft launches" in mid-2003, i.e., non-mass-market launches, without major revenues. Multi-national operators tend to coordinate these delays.[33] Under the current tight fiscal environment, many operators will not be able to meet the 3G roll-out commitments they agreed to when they received their licenses. One market that looks somewhat optimistic is S. Korea, where the data indicate greater usage of the new sophisticated handset features and data revenues are increasing.

Planning for the Future—Beyond 3G

For several years, the mobile services industry has been thinking about the next steps to develop mobile communications capabilities beyond 3G. The demand for more robust mobile networks is expected to continue to increase, even after deployment of 3G, to provide enhancements to existing mobile telephony services and greater bandwidth capacity. One of the characteristics of the next generation of mobile services will likely be an even greater global compatibility, giving users and information devices the capability to roam across a variety of heterogeneous network environments, to operate in various frequency bands, and to use a variety of air interface standards to optimize the use of spectral resources.

Manufacturers are already planning for the introduction of a universal radio, which would be able to automatically change frequency channels and adapt to different

[30] *Interoperability, IPR,Hang Over 3G*, CR Wireless News, November 11, 2002.

[31] *Raise Your Glass to BREW*, Computer Technology Review, March 2001.

[32] Global Telecoms Monthly, Salomon Smith Barney (a member of Citigroup), 12 September 2002, page 8.

[33] 3G Rollout Status, Northstream version 1.2, 4 October 2002.

air interfaces depending on the communications link. These systems will also provide greater bandwidth through more efficient use of existing spectrum and (the industry hopes) additional spectrum allocations. These systems would employ new modulation techniques, intelligent antennas, pico-radios interference detection and multi-user detection, and reconfigurable, self-healing networks to support videoconferencing, video-on-demand, higher speed Internet access, large file transfers, and emergent m-commerce applications.

In some countries (e.g., Japan and Korea) these futuristic capabilities are referred to as fourth generation mobile communications systems (4G). S. Korea and Japan are already jointly planning for the implementation of 4G services. In other regions (e.g., the EU and in ITU meetings) the term "beyond IMT-2000" is preferred, perhaps to give mobile service providers time to deploy 3G services and allow 3G to fully mature. The ITU even differentiates between "enhancements" or improvements to IMT-2000 systems, and systems beyond IMT-2000. Throughout the policy development process and the international negotiations on 3G and beyond, the U.S. position has been and remains technology neutral. As a result, U.S. policy makers are not as entangled in the debate over standards or nomenclature as our counterparts in most other countries. We continue to advocate for other countries to adopt a similar approach.